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ABSTRACT. Flier-cosmonaut of the USSR Colonel G. Titov answers readers' questions on the subject of the "man and machine" problem in cosmonautics and what is the role played by man in the piloting of space ships supplied with advanced complex automation facilities.

TWENTY YEARS OF SPACE

"The first satellite, the first automatic station for investigation of /4* the Moon, the first interplanetary flight and finally, the first flight of man. These are the glorious markers of the first years of the space era, placed along the highway of history by the Soviet people, the builders of communism."

These are the words of Yuriy Alekseyevich Gagarin, the man who pioneered space navigation.

After this flight our country anticipated many new victories in the mastery of space. These are indicated by the pennants delivered to the Moon and the planets by Soviet automatic space stations (see the first page of the cover).

Twelve years have passed since the first artificial earth satellite proclaimed to the world the era of the mastery of space by man. The capability of flights into space and the validity of associated decisions concerning varied and complex scientific technical problems were proved by this outstanding event.

Since that time hundreds of space objects of varied purpose have been launched into near-earth orbits.

Investigations conducted from satellites have significantly changed out concepts concerning spatial regions near the Earth and have clarified the profound relationships between the processes which occur on the Sun and near the Earth.

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*Numbers in the margin indicate pagination in the foreign text.

The use of satellites has opened broad prospects in the development of communications, weather forecasting, improvements in navigation and ionospheric and solar work.

A great distance has been traveled in 12 years. Soviet interplanetary stations were the first to photograph the back of the Moon, were the first to reach the Moon, accomplished a soft landing on the surface, and became artificial satellites of the Moon. The successes of Soviet science in the investigation of Venus are well known. In May this year the Soviet automatic probes "Venus-5" and "Venus-6" carried out a large complex of scientific investigations in the atmosphere of this planet and placed flags on the surface with a bas-relief of Vladimir Il'yich Lenin.

The past year of space has been filled with events. The flights of the "Soyuz" crafts were accomplished with cosmonauts G. T. Beregov, V. A. Shatalov, B. V. Volynov, Ye. V. Khrunov and A. S. Eliseyev; during these flights the ship systems were tested, the docking of piloted craft was accomplished for the first time, passage from ship to ship through open space became a fact and the first experimental scientific station was created. The number of satellites of the "Cosmos" series reached 300. Unique investigations of Venus were carried out by means of automatic interplanetary stations.

American astronautics has also scored great successes during the current year. Scientists, engineers and astronauts of the USA have solved the most difficult problem by providing for a landing of astronauts on the Moon (see the comentary concerning the flight of "Apollo-11" on page 46).

The study and mastery of space continues.

Let me begin with an example borrowed from aviation. I do not do this because of my desire to look like a school pupil asked to talk about Africa by his geography teacher and who answers that he would talk about Europe first. I do not do this in the least because of the fact that I came to cosmonautics from aviation and that I am a flier by profession. In my view the example I am giving will simply enable the readers more clearly to visualize the complexity of the problem described in engineering psychology as "man and machine." The importance and the topical nature of this problem have become particularly noticeable in recent years, when man was faced with tremendous velocities, the control of most complex systems and the processing of a large volume of information, processes which are taking place exceptionally rapidly.

Imagine a jet airplane flying three times as fast as the speed of sound. The pilot at the controls of such an aircraft develops a "blind" space which he is unable to perceive. It seems to him that the objects he has noticed are 100 meters ahead of the plane whereas in fact they are already behind it.

Why does this occur? A certain time is required for the nervous excitement to be transmitted from the sensory organs (in this case from the eyesight) to the brain and for man to become aware of the information supplied to him and have the corresponding motor reactions. This time, as proved experimentally, ranges from 0.1-0.2 seconds. In the past, when man was not faced with high velocities or rapidly developing processes, he had no difficulty in guiding flying engines. The insufficient speed of his nervous-mental processes did not bother him. At the present time the situation has changed drastically.

Ten years ago engineers and psychologists had a major discussion on "man or machine?" The problem could be understood approximately in terms of "Who whom?" The machine partisans claimed that automatic systems could do everything alone and can fully take over the human functions. It was claimed that man with his sensory organs had become hopelessly obsolete and incapable of controlling machines requiring a fast reaction.

The arguments of the supporters of automation seemed irrefutable. Physicians and psychologists had sufficient data on the "imperfection" of man and

automated systems were already controlling electric power plants and gas pipelines as well as piloting aircraft. "Thinking" machines composed music, translated texts from foreign languages and diagnosed patients. Science fiction writers, looking ahead, depicted automatic machines which, through self-training and organization, would become more intelligent and stronger than man, would clash with man and, in the final account, dominate him. One such conflict is described in the film "2001: A Space Odyssey," whose script was written by Arthur Clarke. It describes the mutiny of a robot which, together with astronauts, is engaged in a flight to the planet Jupiter.

However, in my view this concept of an automated system is somewhat one-sided. Man is continuously growing and improving along with the improvement and creations of his hands and his mind. However, man always stays ahead. Yes, it is true that man computes slowly and inaccurately; the volume of information which he is capable of processing within a certain time unit is small; his activity is limited (he must rest and thus rebuild his physical and mental energy). In all this he is inferior to the machine. Yet, the machine is unable or almost unable to correct its own errors. In terms of its choice of methods of action it is limited by its program. It cannot operate without being given complete information.

Furthermore, even the most perfect machine cannot match the memory volume of the human mind. Man rarely adopts foolish decisions and would not follow the formal logic of the "machine brain" should it conflict with common sense. Yet, this happens quite frequently with a machine.

The most important thing which distinguishes man from machine, however, is his capability to act sensibly and creatively under unforseen and unprogrammed situations; this is an ability partially based on the work of something still unmodeled: the subconscious; intuition.

This is what Academician A. N. Kolmogorov said on this subject. In the mind of man the "apparatus of formal thinking does not hold a central position." A tremendous, still unstudied area of the subconscious stretches between the simplest reflexes and the formal human logic (whereas a machine can function only on the basis of formal logic).

After sober considerations, weighing the positive and negative aspects and convinced that man will be never excluded from data control systems, the engineers and psychologists reached the conclusion that the best way to formulate the "man or machine?" problem was in terms of "man and machine." Now the former opponents who defended different viewpoints have joined forces and undertaken the search of methods for upgrading the reliability of the human link in the man-machine system. Today they consider as their main objective the sensible distribution of functions between man and machine and the selection, instruction and training of operators and the rational organization of the supply of information, its perception by the operator and its rapid processing.

Let us now take up the main topic of our conversation: man and automatic machine is space.

In astronautics, as in any other area of human activities, the specialists are trying most rationally to divide the duties among automated machines and man and find the optimal variant for their combination.

The opportunities offered by automatic systems in the study of space are tremendous. This has been quite vividly demonstrated of late by the Soviet interplanetary "Venus-5" and "Venus-6" stations which smoothly dropped into the atmosphere of a remote planet and carried out a large number of unique scientific studies. This experiment convincingly proved that automatic equipment is necessary for the study of largely unknown conditions.

Yet, however great the possibilities of satellites and automatic stations may be they cannot replace the various creative possibilities offered by man. An automatic machine is unable to study that which is essentially unknown. It can study only processes which are, to a certain extent, familiar to man.

In the course of study man alone can analyze the achieved results, take the right decisions under unforeseen circumstances and make full use of the available possibilities for the study of the universe which surrounds us. At the same time it is entirely clear that, until the total safety of human flights in space has been secured, automatic machines will remain the principal means for space navigation.

A variety of automated systems and mechanisms are found in a space ship, together with man. They help him pilot the ship and are "concerned" with his life in space.

However, precisely what are automatic machines supposed to do in a space flight and what are men, the crew, supposed to do?

Here no prescription can be followed. The division of duties will vary, depending on whether or not the ship is orbital or interplanetary; the flight program, the nature and volume of scientific research and, finally, the crew structure would have a great impact.

However, taking several characteristic functions in the control of space ships as an example we may describe the role of man and his place in the chain of control.

One of the functions in the control of space ships is that of controlling and analyzing the state of the equipment and the various systems on board ship. Remember reports from outer space: "All systems are go." Should control over the ship systems be given to the crew, it would lose a great deal of time and effort in interpreting this information. It is best to let automatic systems do this part of the work. In case of error such machines would tell the cosmonauts where the error has happened and what is to be done to eliminate it. Consequently, man interferes in the work of the automatic systems only in the case of breakdowns in their work. Such extreme situations may not occur during a flight.

Here is another example: "The links within the ship control system are /6
the following: instruments determining the position of the ship in space and its deviation from its planned position; indicators telling the cosmonauts the results of such measurements; the cosmonauts themselves; the converting and boosting control systems; the executive organs; the engines and many others. The role of man here is relatively simple: on the basis of the data received he determines the problem to be fed to the computer. Here again, however, man can successfully replace the computer. However, it would be inexpedient to entirely eliminate man from controlling the guidance of the ship. Man, if necessary, must be able to assume this control himself.

Why is this? First of all, in order to carry out the flight assignment more efficiently and more rationally. Automatic systems work under certain regimes. Man could do the same under different regimes which, considering the existing circumstances, would best contribute to the solution of the problem. Secondly, it is done for the sake of improving reliability (in the opposite case, should an automated guidance system break down, for example, the landing of the ship from its orbital position would be impossible).

In this connection man becomes more active. Here again, however, he interferes in the work of the automatic machines only if necessary.

Here is another example.

In recent times space ships have been equipped with guided landing systems which makes possible a substantial reduction in the overload and an increased landing accuracy. Since, as we know, landing is the most essential aspect of the flight, it would be risky to entrust it to automatic systems alone. It has been deemed expedient for the cosmonaut to duplicate the work of the automatic systems in landing. In this case any fault in the work of the automated systems would have no influence on the landing since the cosmonaut would immediately assume control of the ship.

The same could be said of guiding space ships in docking. If the search and the closing down may be entrusted to automatic machines, one should watch closely when the distances are small and when the ships couple. Here the cosmonaut must be able to take over rapidly with manual controls should the automatic equipment operate unsatisfactorily, for whatever reason. Thus the presence of man aboard ship considerably increases the reliability of the operation of the automated systems.

All this, you may say, does not require man's creative talents and, should we be able to design reliable automated systems, we could do without man. No one would object to this. However, we are still far from the time when reliability guaranteeing total flight safety without human participation will be achieved.

In such a case what would be a truly sensible approach to the allocation of functions to man and automatic machine? The automatic machines must measure, regulate the dynamic processes and the work of the systems, control their state and supply the crew with processed data and with a ready evaluation of the state of the systems. They must formulate recommendations and forecasts. Using this data, the crew will choose and adopt decisions on doing the work, on the research and on the flight.

Clearly, the interplanetary space ships will be supplied with autonomous navigational systems. Here the role of man will be exceptionally great. The cosmonauts will determine the orbit parameters, the volume of correcting thrusts and the duration of the performance of the engines. They will also deal with the solution of other problems directly linked with the success of the flight.

Therefore, the human control possibilities will be maximally utilized aboard ship. Sufficient scientific data has been acquired to claim with full justification that in space, and in a state of weightlessness, man can accomplish as much as on earth. Naturally, here maximal use is made of everything developed in the field of automation in the field of aircraft building: automatic pilot, radar, and all the sophisticated systems used in modern aircraft.

Therefore, the heart of the matter is not so much what man or machine could or could not accomplish but how better to resolve the problem of upgrading the reliability of the system and ensuring the safety of space flights.

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